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REPORT 431

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ADVISORY GROUP FOR AERONAUTICAL RESEARCH AND DEVELOPMENT
64 RUE DE VARENNE, PARIS VII

REPORT 431

A FLIGHT TEST METHOD FOR THE EVALUATION OF APPROACH AND RUNWAY LIGHTING EFFECTIVENESS

by

T. VAN OOSTEROM

JANUARY 1963

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A FLIGHT TEST METHOD FOR THE EVALUATION OF APPROACH AND RUNWAY LIGHTING EFFECTIVENESS

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T. van Oosterom

This Report was presented at the Aircraft Take-Off and Landing Specialists' Meeting,
sponsored by the AGARD Flight Mechanics Panel, held in Paris, 15-18 January 1963

SUMMARY

A flight operational method for evaluating the effectiveness of visual approach and landing aids is described.

The method is based on a quantitative appraisal of the guidance obtained from a given configuration of lights by measuring the quality of the approach and landing and by determining the pilot's effort in carrying out these manoeuvres.

To this end, relevant flight technical and physiological measurements are made and the test results are expressed in quality marks by means of a specially developed interpretation procedure.

For simulating consistent and marginal weather conditions a cockpit fog simulator has been developed consisting of a gyro- and altitude-controlled movable opaque screen mounted in front of the subject pilot. The safety pilot is not subjected to any restriction of visibility.

The tests are performed on a statistical basis so that the real significance of the differences in effectiveness between light configurations as found from the trials can be determined.

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SOMMAIRE

Une méthode est décrite pour évaluer l'efficacité des moyens visuels d'approche et d'atterrissage par des essais en vol.

La méthode est basée sur une appréciation quantitative du guidage obtenu d'un certain configuration de feux en mesurant la qualité de l'approche et de l'atterrissage et en déterminant l'effort du pilote lorsqu'il effectue les manoeuvres correspondantes. A cet effet, des mesures techniques de vol et des mesures physiologiques appropriées ont été effectuées et les résultats de mesure sont exprimés en notes de qualité au moyen d'un procédé d'interprétation spécialement développé.

Pour simuler des conditions de visibilité restreinte consistantes et marginales un dispositif a été développé et installé dans le cockpit. Ce dispositif, comportant un écran opaque mobil asservi d'un gyroscope et d'un altimètre, est monté devant le pilote soumis à l'épreuve. Le pilote de sécurité assis à côté, ne subit aucune restriction de visibilité.

Les essais sont exécutés d'après les conceptions statistiques de sorte que les différences en efficacité des configurations de feux, ressortant des essais, soient significantes.

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NOTATION

s	screen position
θ	longitudinal attitude of aircraft axis
h	height of pilot's eye
ϕ	sight angle
z	visual range
a	(see Figure 1)
α	screen angle (see Figure 1)
t	time
w	rate of descent
E	illumination
r	distance between pilot's eye and light source

A FLIGHT TEST METHOD FOR THE EVALUATION OF APPROACH AND RUNWAY LIGHTING EFFECTIVENESS

T. van Oosterom*

1. INTRODUCTION

The improvement of the effectiveness of visual landing aids is continuously receiving considerable interest in several countries. Better visual information to the pilot from approach and runway lighting makes aircraft operation less dependent on weather conditions at destination. Also, in future automatic landing, these lighting systems will play an important part for monitoring the landing procedure.

In the Netherlands this interest has resulted in an active participation in international conferences on standardization of airport lighting and in the last few years these activities have been extended to the flight operational evaluation of proposals for improving existing systems.

In this Report a method will be described which has been developed and applied for this last purpose. The main feature of this method is to exclude any subjectivity in the assessment of the systems involved and to create a statistical basis for the evaluation procedure.

2. OUTLINE OF THE EVALUATION METHOD

The method is based on the principle that the effectiveness of the guidance obtained from a certain configuration of lights during the approach and landing must - for a given type of aircraft - be apparent from

(a) the quality of the approach,

(b) the quality of the landing,

(c) the pilot's effort to carry out the approach and landing.

The effectiveness may, moreover, be illustrated by the pilot's judgement and understanding of the guidance obtained.

The *quality of an approach and landing* can be fairly well assessed by:

- The actual flight path in horizontal and vertical projection until touch-down;
- The height at the moment of passing the runway threshold;
- The distance between the threshold and the actual touch-down point;
- The vertical deceleration of impact at touch-down.

The *pilot's effort* has hitherto been assessed from information on:

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- The deflections of elevator, rudder and ailerons; and
- The frequency of the pilot's heart beat.

The data required for the assessment of approach and landing quality and of the pilot's effort are obtained by recording the indications of the relevant aircraft instruments and of special instruments installed for this purpose in the aircraft and on the ground. The determination of the flight path of the approaches before passing the runway threshold is based upon the deflections from the ideal ILS flight-path. For this purpose the outputs of the ILS glide path and localizer receivers are recorded, this being a typical in-flight measurement. The landing flight-path (beyond the threshold), on the other hand, is recorded by ground cameras.

The *pilot's judgement* on the guidance obtained from a certain system is derived from the answers collected by systematically and carefully questioning the pilot shortly after the performance of each test flight.

The quality of the approach and landing as well as the pilot's effort and judgement will be greatly influenced not only by the effectiveness of the guidance of a certain configuration of lights but also by the prevailing weather and by the initial flight condition of the aircraft. Moreover, the performance of different pilots, even if flying under exactly the same conditions, will by no means be the same. Fundamentally, the test procedure, therefore, must be such that data, enabling the above-mentioned three criteria to be assessed, are recorded in marginal weather (real or simulated) with a number of pilots large enough to eliminate personal influence on the final results and for different initial flight conditions. A complete evaluation should, moreover, be based on tests with different types of aircraft.

In experiments of this nature the influence of the *weather* is perhaps the most troublesome problem. For the purpose of the investigation these tests have to be performed under marginal and invariable visibility conditions, which, however, occur but seldom. In view of the continuity and the reliability of the tests, therefore, it is of utmost importance to find a method of simulating consistent marginal conditions. This simulation has been achieved by fitting, immediately behind the cockpit window, a movable screen, especially designed for the purpose of limiting the subject pilot's visual field to obtain a constant visual range such as prevails in homogeneous fog, independent of the longitudinal attitude and the height of the aircraft. For this constant visual range a low value (e.g. 1000 feet) can be chosen in order to emphasize possible differences in guidance characteristics of the light patterns to be compared. In order to simulate seeing conditions in fog as realistically as possible, a reduced value of the luminous intensity of the lights has to be chosen. Moreover, a neutral and a slightly diffusing filter are placed before the pilot's eyes. This simulation of seeing conditions in fog requires a good meteorological visibility during the test flights.

The safety pilot in the second seat has at his disposal all the available visual guidance without any limitation, in addition to the information provided by the instruments. This means a great advantage above flying tests in real fog or in smoke, the safety pilot in this case being also subjected to restricted visibility.

In order to eliminate the influence of the *personal characteristics* of the subject pilot as far as possible, the number of subjects involved in the tests must be such that the overall result can be regarded as characteristic for a great many pilots. The scatter of the results of a preliminary investigation of three light configurations carried out with five pilots indicated that at least 15 pilots should be included in investigations of this type, if each pilot carries out one test flight on each light pattern and from each initial position (see below).

To ensure that the results will not be entirely dependent upon the influence of the drill followed in a particular training schedule, subject pilots with different training and experience should participate in the tests.

A complete assessment of the influence of the *initial flight condition,* when the subject pilot establishes visual contact, on the quality of the approach and landing would require a very extensive flight test programme in view of the great number of variables involved (e.g. horizontal and vertical deviation from the ideal flight path, angles of pitch and bank, heading and speed). In order to restrict the number of flights, three standardized initial positions have been chosen:

(a) The ideal position: on the ILS glide path and on the runway centre line;

(b) On the centre line and 2 dots ILS deflection above the glide path (i.e. about 50 feet above the glide path at the locator where the glide path height is 200 feet); and

(c) On the glide path and 1 dot ILS deflection left of the centre line (i.e. about 100 feet left of the glide path at the locator).

In these initial positions, also an appropriate standard aircraft configuration and standardized power, speed and attitude conditions are maintained.

It is desirable to have each pilot carry out one approach from each of the three initial positions on each of the light configurations to be assessed. In this way no appreciable familiarization with local conditions occur to cause the differences in the systems under examination to be largely levelled out. The order of the light systems and the order of the flights with a specific light system have to be chosen at random in view of unavoidable influences such as fatigue, and variations in direction and speed of the wind, etc.

3. METHOD OF FOG SIMULATION

The device capable of simulating a constant visual range as prevailing in fog of homogeneous density has been developed by the National Aeronautical and Astronautical Research Institute (NLR). The visual range should be kept constant irrespective of the longitudinal attitude and the height of the aircraft during the approach and the landing manoeuvre. The desired simulation is obtained by limiting the pilot's visual field by an opaque movable screen attached to the cockpit window. As illustrated in Figure 1, the upper limitation of the visual sector is determined by the lower edge of the movable screen and the lower limitation is unaffected and is defined by the shape of the cockpit cut-off. To avoid a reduction of the visual range with decreasing height, the screen has to be raised slowly during the approach at a rate dependent on the rate of descent of the aircraft. When the aircraft is flying at high altitude, the cockpit window is completely masked by the screen. When the aircraft has descended to the height where the distance from the ground - measured in the direction of the cockpit cut-off - is equal to the visual range to be simulated (the visual sector and segment thus still being zero), the driving gear of the screen is switched on so that the bottom edge of the cockpit window begins to clear. Provision to ensure that the visual range is not affected by alterations in the longitudinal attitude of the aircraft is made by gyroscopic stabilization. A constant value of the visual range is obtained with the screen moving according to the principles just described, provided that the pilot's eyes have a fixed position relative to the aircraft. This has been obtained by means of a head support firmly attached to the screen frame. The head support also carries a combination of filters which, together with a convenient setting of the luminous intensity of the lights, simulates seeing conditions in fog.

Figure 3 shows which part of the three light configurations is visible beneath the screen when the aircraft is at heights of 160, 130, 100 and 70 feet respectively for a visual range of 1000 feet. Figure 4 gives an impression of what is really seen by the subject pilot of the configurations at these heights.

From Figure 1 it appears that

$$s = a\frac{\sin(\theta + \phi)}{\sin[\alpha - (\theta + \phi)]} \; . \qquad (1)$$

Moreover, the device has to satisfy the basic requirement

$$z = \frac{h}{\sin\phi} = \text{constant} \; . \qquad (2)$$

From (1) and (2) it follows that s must be controlled by θ and h in order to obtain a constant visual range z .

Figure 2 shows a schematic diagram of the screen control system which is basically a servo-system that receives its input θ from a vertical gyro and the input h from a mechanical integrator. This device integrates the rate of descent w according to

$$h = h_0 - \int_0^t w\,dt \; . \qquad (3)$$

The gear ratio of the integrator is manually controlled according to the deflection of a quick-response rate-of-descent indicator. A recent modification makes it possible to obtain the height-input signal directly from an aneroid device, thus enabling complete automatic operation of the system.

The servo-motor is provided with an eccentric disc driving a steel tape, which is coupled to the movable screen. The shape of the disc is determined by Equation (1).

Figure 5 shows the screen device as installed in a C-47 aircraft.

As mentioned before, seeing conditions in fog are simulated in the first place by adjusting the luminous intensity of the lights on the ground to a low value and, moreover, by applying a combination of filters, adapted to this value, in the pilot's head-support. The combination of filters, placed in front of the pilot's eyes in the head-support, consists of a clear neutral filter with a transmission of 10 per cent and a slightly diffusing sheet of perspex with a transmission of 80 per cent. The shape of the filter and the perspex sheet allow the pilot an unobstructed view of his flight instrument panel.

In real homogeneous fog, lights at distances near to the visual range will be attenuated more than in the simulating device just described. This can be seen from Figure 6 giving the illumination on the pilot's eyes from a light source with a luminous intensity of 50 cd as a function of the distance from the pilot to this light source. The curved line A shows the eye illumination when the light source is seen through a homogeneous fog with a meteorological visibility of 1000 feet. The straight lines B and C apply to a clear atmosphere when the source is seen directly (B) and through a filter with a transmission of 8 per cent (C) (i.e. the transmission of the combination of the neutral and the diffusing filter). The Figure shows that in the latter case the lights at a distance from the pilot almost equal to the visual range simulated by the movable screen (1000 feet) are seen brighter than in real homogeneous fog, while at short distance the lights are seen more dimly.

According to the opinion of several subject pilots and many other pilots who have inspected this test installation, it provides a realistic simulation of what is generally observed in fog. For this reason also the Federal Aviation Agency (FAA) applied the NLR-installation during an extensive series of evaluation tests on landing-zone lighting at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, N.J., in 1961.

4. MEASURING EQUIPMENT

Measuring equipment has to be installed in the test aircraft for recording of the quantities, mentioned before, to assess the quality of the approach and landing and the pilot's effort. A multiple trace recorder and a photographic observer have been used for this purpose. In addition, some instruments for checking the proper functioning of the screen installation are applied. A typical recording of the trace recorder (Beaudouin A-1320) is reproduced in Figure 7 showing two types of traces. Firstly, there are the continuous traces produced by the galvanometers. Secondly, marker traces are produced. These traces, in fact, only mark the exact moment at which an event takes place. For instance, the time base is formed by a marker trace connected to an electrical chronometer producing an 'on-off' signal every second and omitting an 'off' signal every 10 seconds.

The *photographic observer* is used to record indications of the instruments shown in Figure 8 (numbers of instruments agree with those of parameters, etc., mentioned overleaf).

On the airfield two *Leica cameras* are placed beside the runway and perpendicular to it for the purpose of recording the landing flight-path.

The following parameters, events and signals are recorded by the trace recorder (referred to below as tr.rec.), the photographic observer (ph.obs.) or the ground cameras:

A. *Parameters describing general flight condition*

(1) Airspeed: indicator (ph.obs.);

(2) Altitude: altimeter (ph obs.);

(3) Longitudinal attitude (angle of pitch) and lateral inclination (angle of bank) (ph.obs.);

(4) Magnetic heading (ph obs.).

B. *Parameters determining quality of approach and landing*

(5) ILS localizer deflection: the input current of the localizer indicator, giving sideways angular deviation from the centre line (tr.rec.);

(6) ILS glide path deflection: the input current of the glide path indicator, giving vertical angular deviation from the ILS glide path (tr.rec.);

(7) Top-axis acceleration (deceleration of impact at touch-down) (ph.obs.);

(8) Actual flight path from threshold until touch-down: the recordings are made by the ground cameras with the shutters continuously open during the landing. The successive images of the aircraft's anti-collision light (the timing of which is recorded as described in item 16) together with the images of fixed reference lights on the ground and of a synchronization lamp behind the cabin window make it possible to determine the flight path in the landing region in correlation with the test data recorded in the aircraft.

C. *Parameters determining pilot's effort*

(9), (10) and (11): Elevator, rudder and aileron deflections (ph.obs.);

(12) Heart-beat frequency: this signal is derived from a small unit incorporating a miniature light bulb and a photo-electric cell, which is clipped to the ear-lobe of the subject pilot. Blood pulses through the arteries vary the amount of light received by the photo-electric cell. Two types of traces are recorded. Both show deviations for each blood pulse, but in one of them the height of the pulse is proportional to the blood pulse frequency also. (For further details, see Reference 2) (tr.rec.).

D. *Parameters determining the visual range actually attained*

(13) Position of cockpit screen (ph.obs.);

(14) Longitudinal attitude (precision measurement) (ph.obs.). (For the calculation of the actual visual range the true height must also be known (see items 2 and 8)).

E. *Event marks and other signals*

(15) Moment of ignition of the synchronization light behind a cabin window. The recording is needed for establishing the correlation between the flight path recordings on the ground and the recordings of the airborne equipment (tr. rec.);

(16) The rotations of the aircraft's anti-collision light by means of a photoresistor in the perspex navigation dome (tr. rec.);

(17) Moment of touch-down. The event marker was controlled manually (tr. rec.);

(18) ILS inner-marker beacon signals, facilitating the identification of the recordings (tr. rec.);

(19) Correlation between the recordings of photographic observer and trace recorder: an instrument with two pointers, rotating at a constant speed of 1.3 and 0.13 revolutions per second respectively, is mounted in the photographic observer. Each time the fast pointer passes the zero mark of the dial a contact is closed resulting in an 'on' signal of a marker trace in the trace recorder;

(20) Time: 'on-off' signals every second (tr. rec.) and split second watch (ph. obs.);

(21) Light signals, indicating 'up' and 'down' positions of the screen (ph. obs.);

(22) Event marker for the indication of other important moments (ph. obs.);

(23) Counter number of every shot (ph. obs.).

Calibration of the ILS signals is achieved by determining the relation between the difference in depth of modulation (DDM) of the ILS transmitters for various deviations from the ILS glide-path in azimuth and elevation, followed by the calibration of the trace recorder for various signals applied to the input of the ILS localizer and glide-path receivers.

The actual visual range obtained during the flight tests can be calculated from the recorded values of longitudinal attitude θ and height h by applying Equations (1) and (2) of Section 3; the value of h is taken from the ground-camera pictures and, for larger altitudes, from the altimeter recordings. Calculations for the installation applied in these tests show that a deviation of ±100 feet from a nominal visual range of 1000 feet was generally not exceeded, except during the final part of the flare-out.

Generally, the simulated visual range in the touch-down region exceeds to some extent the nominal value due to deceleration effects on the vertical gyro.

5. INTERPRETATION OF TEST DATA

From the recordings obtained with the equipment described in the preceding Section the following data can be derived:

(a) *On the quality of the approach*

Approach height (actual flight path projected on a vertical plane parallel to the runway centre line) until threshold;

Approach ground-track (actual flight path projected on a horizontal plane) until threshold.

(b) *On the quality of the landing flight path and the touch-down*

Height (as a function of distance) from threshold until touch-down;

Distance of touch-down point from runway threshold;

Vertical deceleration of impact at touch-down.

(c) *On the pilot's effort*

Control movements;

Pilot's heart-beat frequency during approach and landing.

The data on the actual flight path derived from the recordings are related to the lowest point of the main undercarriage, projected to the aircraft's plane of symmetry.

Some of the data on the quality of the landing and on the pilot's effort can be analysed and compared between light patterns in a rather simple way. Others, especially those determining the flight path, do not easily lend themselves to direct comparison and to statistical analysis. In view of this, a procedure* has been applied by means of which the quality of the flight path during approach and landing can be expressed in one or two figures of merit.

The *quality of the approaches and landings* is expressed in marks based on the shape and the location of the actual flight path. The marks vary linearly from 0 to 10 between unacceptable and ideal performance respectively.

For the *approach quality* the actual flight path is considered from a point 3000 feet before the threshold, when the pilot should establish visual contact, until the threshold. The assessment of the quality of the approach has been based on the 'relative ease' with which the pilot can bring the aircraft into an 'entrance portal' at the runway threshold. This portal is of a rectangular shape and has a height of 16 feet and a width of 30 feet (see Figures 9 and 10). The centre of the portal is chosen at 37 feet above the runway, equal to the average height above the threshold of all flights made during the preliminary investigation referred to in Section 2. The relative ease is in the first place determined by the minimum size of a straight tapered channel by which the actual flight path can be enclosed. The channels corresponding to the quality marks 1 to 10 have a rectangular cross-section with horizontal and vertical sides. The linear dimensions of the entrance cross-sections of the channels are 3.6 times those of their exit sections (located at the runway threshold), permitting a certain channel to be defined completely by its exit section only. Additionally, the axis of an approach channel should run through the above-mentioned entrance portal at the threshold. Two marks for the quality of the approach are determined, one for *approach height* with the aid of Figure 9 and one for *approach ground-track* with the aid of Figure 10.

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* This procedure has been proposed by Mr. F.E. Douwes Dekker of the National Aeronautical and Astronautical Research Institute (NLR), Amsterdam. The numerical data in this chapter refer to landing trials with a C-47 aircraft, referred to in Reference 1.

To obtain full marks (10) for approach height the actual flight path slope should be constant; in other words, the vertical dimensions of the enclosing channel must be zero (see Figure 9). To obtain full marks (10) for approach ground-track it must be possible for the actual flight path to be enclosed by a channel with an initial width of 11 feet tapering to 3 feet at the threshold (see Figure 10). All approach channels with an exit height of more than 27 feet or an exit width of more than 31 feet are judged unacceptable, giving no marks (0) for approach height and approach ground-track respectively. It follows from what has been stated before that no marks (0) are given also in case the axis of an approach channel does not intersect the entrance portal. It ought to be remembered that the slope of the approach channel was not prescribed, because the actual initial position, 3000 feet before the runway threshold, could not be influenced by the subject pilot.

The process of judgement of the approach quality is amended, in-so-far as ground-track is concerned, in case the initial approach position of the aircraft is purposely deviated sideways from the centre line by the safety pilot. The tapering ratio of the channel is then doubled to 7.2, while its axis is curved gradually from the initial direction on to the centre line at the threshold.

The *quality of the landing flight path and the touch-down* is only evaluated in height from the threshold over a length of 2700 feet down the runway, when the touch-down should have been completed, and in the location of the touch-down point. Here also two quality marks, one for *height from threshold until touch-down* and the other for *distance of touch-down from threshold,* are determined. The quality mark for height from threshold until touch-down is again considered to be determined by the minimum size of a tapering channel by which the actual flight path can be enclosed.

The shape and the dimensions of the channels are chosen on the basis of the following considerations (see Figure 11).

For a landing flight path and a touch-down judged with the highest quality mark (10), the aircraft should pass the threshold at some height within the entrance portal and descend with a constant slope of 2.5^0 until flare-out. Moreover, the landing should be continued by following a flight path parallel to the one corresponding to a height at threshold of 37 feet and a distance of touch-down from threshold of 1000 feet, the flare-out starting at a height of 11 feet and covering a distance of 400 feet. This defines the channel of zero thickness of Figure 11, to which the highest quality mark for height from threshold until touch-down and for the touch-down itself (10) is attached. To allow for passing the threshold at an arbitrary height within the entrance portal, the channels may be displaced 200 feet forward or backward, which also means that a touch-down qualified with mark 10 may occur at a distance between 800 and 1200 feet.

No marks (0) are given for height from threshold until touch-down, when the touch-down takes place at a distance of 1000 feet from the threshold after having passed the threshold at a height of less than 1 foot. The vertical distance between this height of 1 foot and the height of the centre of the entrance portal (37 feet) is divided equally over the channels belonging to the marks 1 to 9. The vertical position of the upper and lower boundaries of the channels near the threshold is symmetrical with respect to the channel with mark 10. The upper boundary of the channel with mark 1 is further determined by the requirement that the point of touch-down is not allowed to be more than 2700 feet beyond the threshold. This means that the height above the runway is considered unacceptable (quality mark 0) when it surpasses a value varying from 89 feet at threshold to zero at 2700 feet beyond threshold. The height of 89 feet corresponds with the point of intersection of the upper boundary of the channel carrying quality mark 1, with the vertical line through the extreme left threshold position, when the grid of Figure 11 is displaced 200 feet in the landing direction.

The second quality mark (for the distance of touch-down from the threshold) is read off from the scale along the horizontal axis of Figure 11. It has already been stated that full marks (10) are obtained when the touch-down occurs between 800 and 1200 feet. The scale shows that, when making allowance for passing the threshold at an arbitrary height within the entrance portal, zero quality mark (0) for touch-down distance is obtained when the distance from the threshold is less than 300 or more than 2700 feet.

Some corrections have to be applied to the several quality marks determined according to the procedures just described. The quality marks for approach height and approach ground-track may be corrected for deviations in actual runway visual range from the intended value by adding to or subtracting from both marks one point where this deviation is more than 100 feet shorter or longer than the nominal one respectively. The quality mark for touch-down is corrected for rough landings by subtracting one point for every 0.5g vertical deceleration at the impact.

For the appraisal of the *pilot's effort* based on the recordings of the control movements and of the pilot's heart-beat frequency, a 'travel index' and a 'heart-beat factor' are introduced respectively. For the travel index a figure proportional to the total travel of elevator, rudder and ailerons over a certain period is deduced from the recordings. This period is taken from 5 seconds before until 10 seconds after passing the inner marker. The heart-beat factor is the ratio of the heart-beat frequency of the subject pilot at touch-down to that just prior to the approach, when the subject pilot is already in his cockpit seat but not yet flying the aircraft.

The quality marks and numerical data in which all test results can be expressed by the methods just described are suited to analysis by statistical methods. This presents a mathematical basis to determine whether differences in effectiveness between light configurations, as found from the trials, are significant or only due to scatter.

6. CONCLUSION

The test procedure described in this paper is characterized by:

(a) The use of airborne recording equipment for collecting quantitative data determining the quality of the actual flight path from the beginning of the final approach until touch-down as well as data on the pilot's effort (control movements, heart-beat frequency) to establish approach and landing.

(b) The application of a movable screen before the pilot's eyes which, in combination with suitable filters and a convenient adjustment of the luminous intensity of the lights on the ground, simulates weather conditions in homogeneous fog.

(c) The elimination of the influence of personal characteristics in the test results and of subjective interpretation of these results by applying statistical methods in the set-up of the test programme as well as in the evaluation of the test results.

It is believed that this method offers a reliable basis of comparison of the effectiveness of the guidance obtained from visual aids during approach and landing. This is confirmed by practical experience in applications of the method in the Netherlands.

7. CONCLUDING REMARK

The cockpit fog simulator described in this Report would also be useful for training and proficiency checking of pilots in 'phase 2' operations.

REFERENCES

1. de Boer, J.B. van Oosterom, T.	*Flight Operational Evaluation of Approach and Runway Lighting.* De Ingenieur, No. 49 and 51, 1961.
2. Harten, G.A. Koroncai, A.K.	*A Transmission Cardiotachometer for Continuous Measurements on Working Persons.* Philips Technical Review, 1959/60, p. 304.

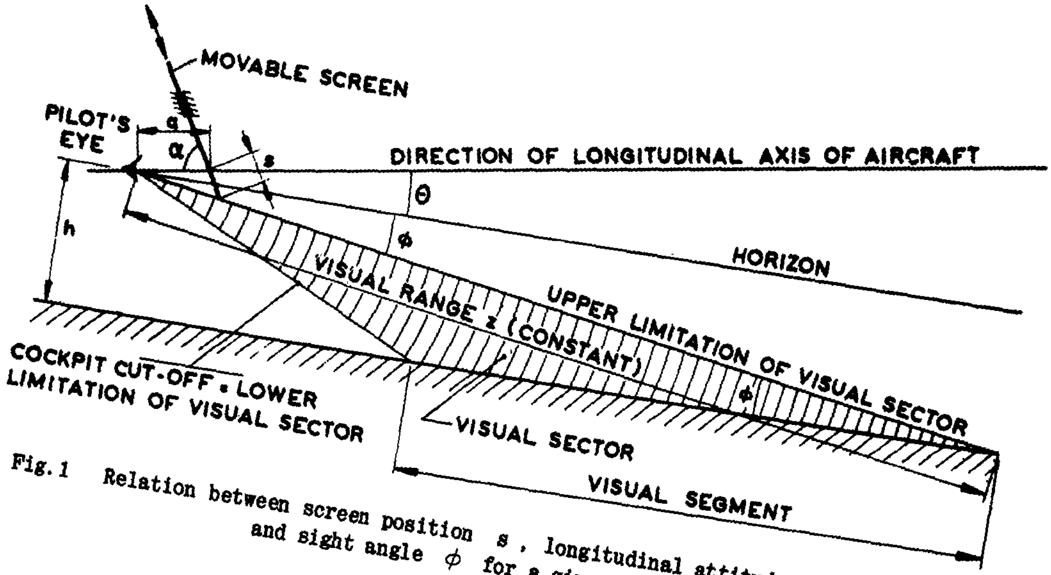

MOVABLE SCREEN
PILOT'S EYE
a
α
s
DIRECTION OF LONGITUDINAL AXIS OF AIRCRAFT
Θ
φ
h
HORIZON
VISUAL RANGE z (CONSTANT)
UPPER LIMITATION OF VISUAL SECTOR
φ
COCKPIT CUT-OFF = LOWER LIMITATION OF VISUAL SECTOR
VISUAL SECTOR
VISUAL SEGMENT

Fig. 1 Relation between screen position s, longitudinal attitude θ, height h and sight angle ϕ for a given visual range z

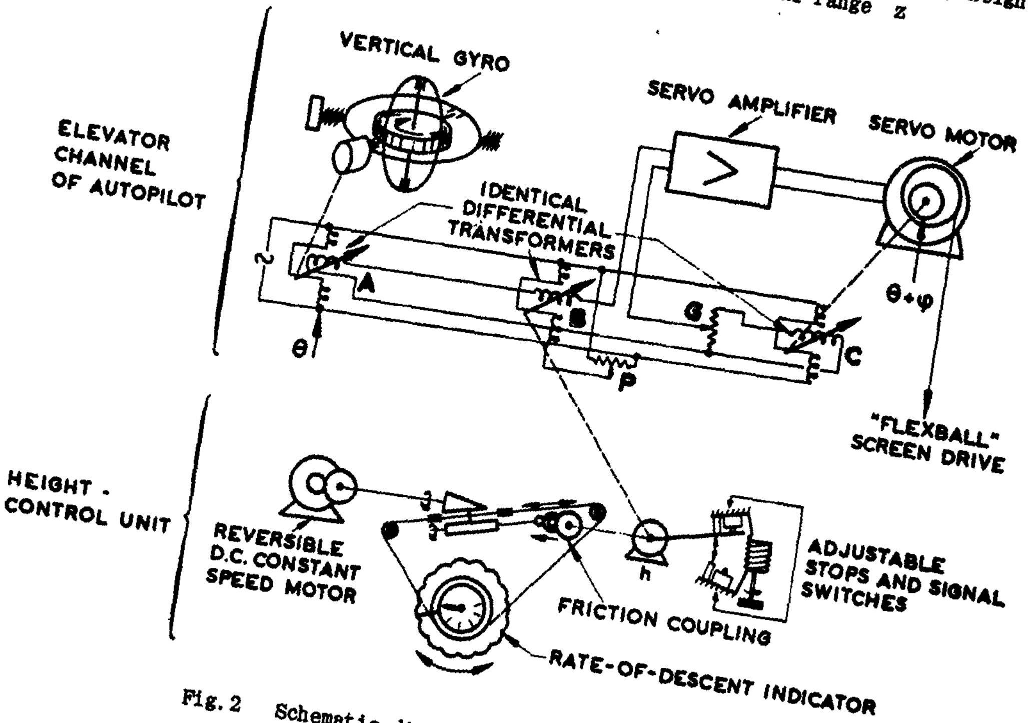

VERTICAL GYRO
SERVO AMPLIFIER
SERVO MOTOR
ELEVATOR CHANNEL OF AUTOPILOT
IDENTICAL DIFFERENTIAL TRANSFORMERS
~
A
B
G
C
P
θ
θ+φ
"FLEXBALL" SCREEN DRIVE
HEIGHT - CONTROL UNIT
REVERSIBLE D.C. CONSTANT SPEED MOTOR
FRICTION COUPLING
h
ADJUSTABLE STOPS AND SIGNAL SWITCHES
RATE-OF-DESCENT INDICATOR

Fig. 2 Schematic diagram of screen control system

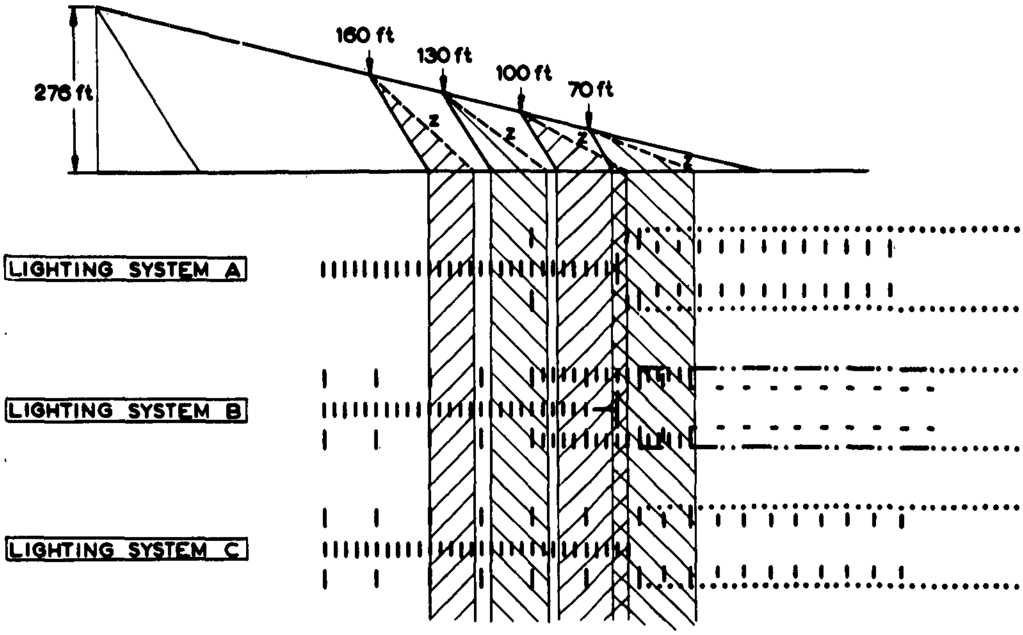

276 ft
160 ft
130 ft
100 ft
70 ft
z
z
z
z
LIGHTING SYSTEM A
LIGHTING SYSTEM B
LIGHTING SYSTEM C

Fig. 3 Visual segments as determined by screen position at heights of 160, 130, 100 and 70 ft for a visual range z of 1000 ft

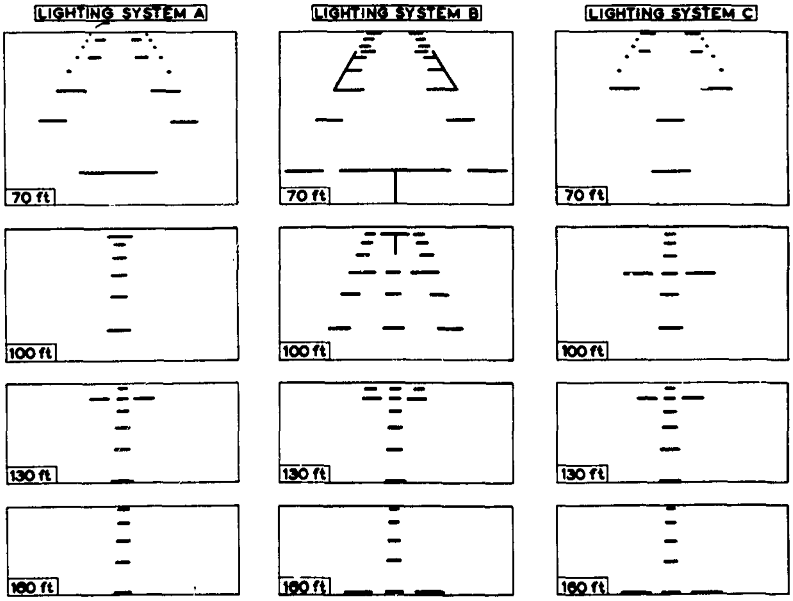

LIGHTING SYSTEM A
LIGHTING SYSTEM B
LIGHTING SYSTEM C
70 ft
70 ft
70 ft
100 ft
100 ft
100 ft
130 ft
130 ft
130 ft
160 ft
160 ft
160 ft

Fig. 4 Visual segments as seen by subject pilot at heights of 160, 130, 100 and 70 ft

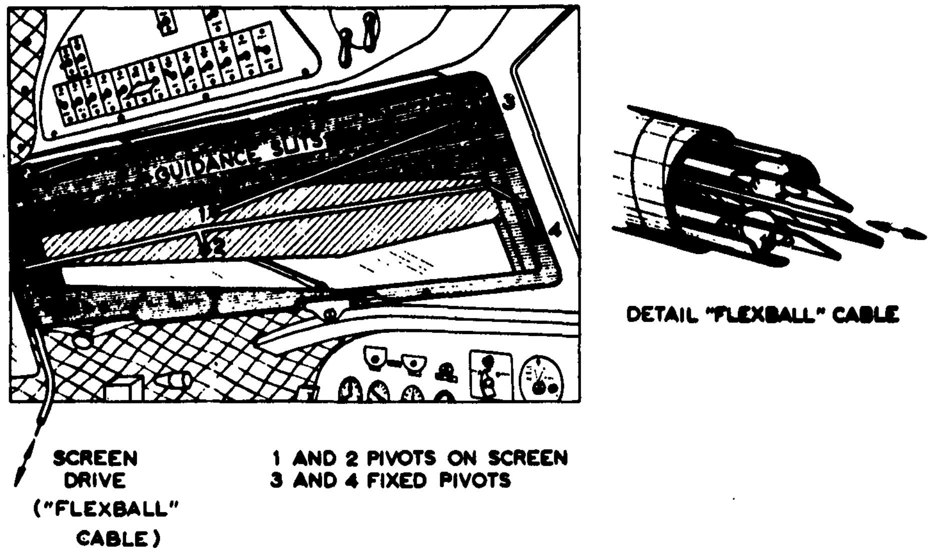

1
2
3
4
DETAIL "FLEXBALL" CABLE
SCREEN DRIVE ("FLEXBALL" CABLE)
1 AND 2 PIVOTS ON SCREEN
3 AND 4 FIXED PIVOTS

Fig.5 Sketch of cockpit screen

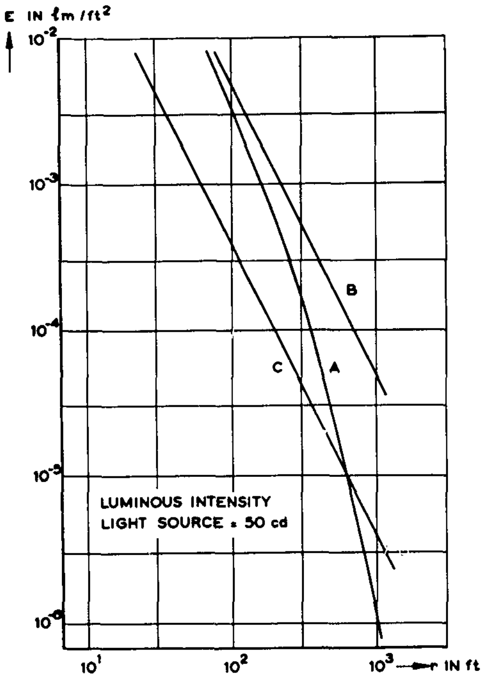


Fig.6 Illumination E on the pilot's eye in homogeneous fog with a meteorological visibility of 1000 feet (A), clear atmosphere (B) and through neutral filter (C) as a function of distance r between pilot's eye and observed light source

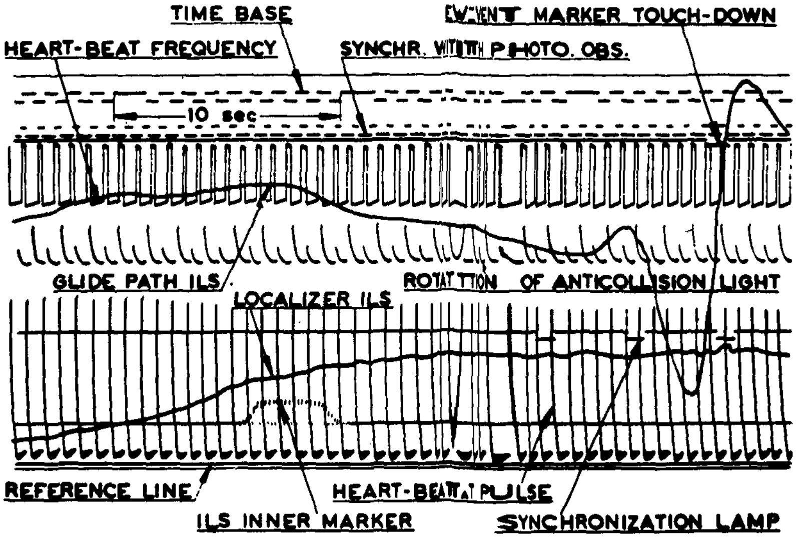
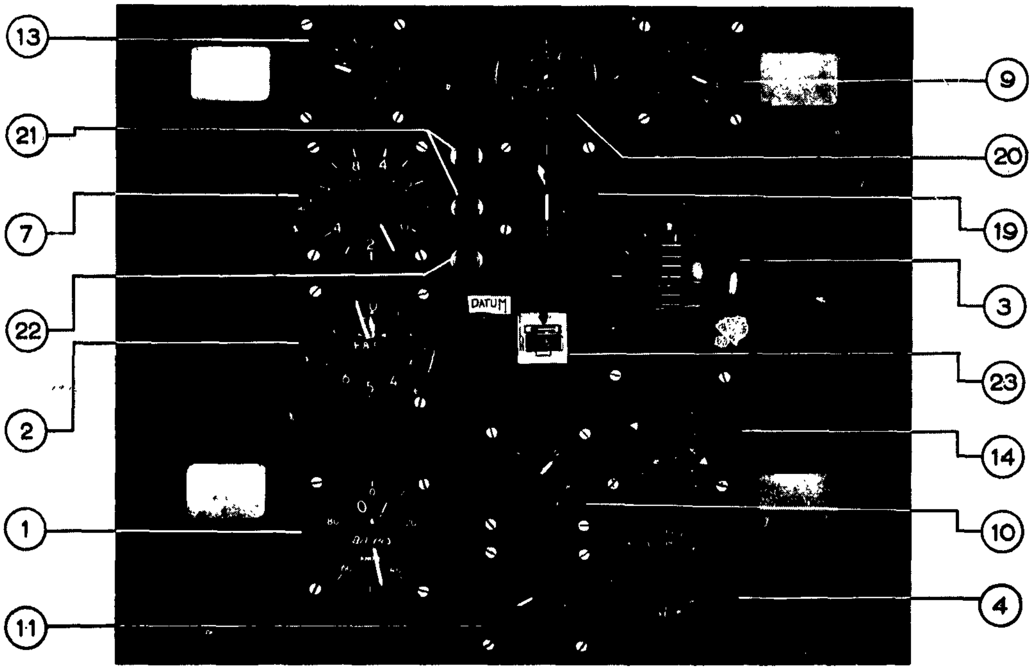


Fig. 7 Typical multiple trace recording



1. Airspeed indicator

2. Altimeter

3. Artificial horizon (pitch and bank)

4. Gyrosyn slave indicator (magnetic heading)

7. Top-axis accelerometer

9. Elevator deflection indicator

10. Rudder deflection indicator

11. Aileron deflection indicator

13. Screen position indicator

14. Precision gyroscopic longitudinal attitude indicator

19. Synchronizer (one rev. long pointer in 0.7 sec. closing contact in 12 o'clock position exactly)

20. Split second watch (one rev. every 6 sec)

21. Light signals for 'up' and 'down' position of ϕ-control unit

22. Event marker

23. Counter

Fig.8 Typical picture of photographic observer

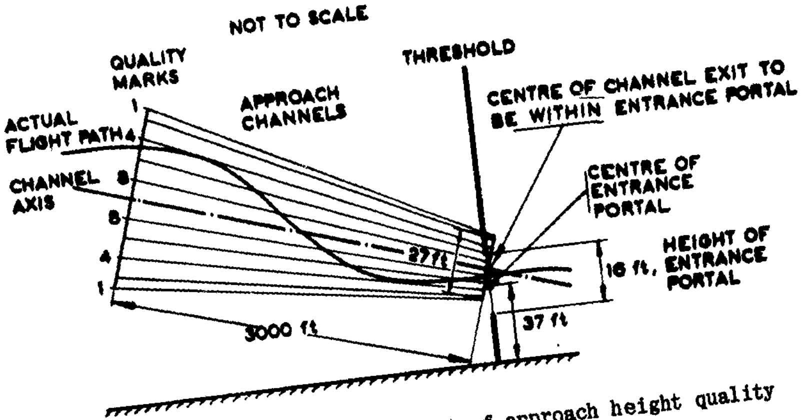

NOT TO SCALE
QUALITY MARKS
THRESHOLD
APPROACH CHANNELS
CENTRE OF CHANNEL EXIT TO BE WITHIN ENTRANCE PORTAL
ACTUAL FLIGHT PATH
1
4
CHANNEL AXIS
8
8
4
1
CENTRE OF ENTRANCE PORTAL
HEIGHT OF ENTRANCE PORTAL
27 ft
16 ft,
37 ft
3000 ft

Fig.9 Principle of assessment of approach height quality (example: approach height mark 4)

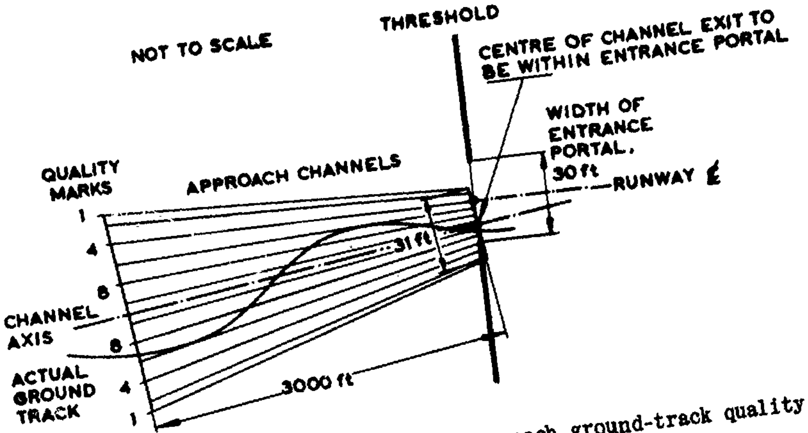

THRESHOLD
NOT TO SCALE
CENTRE OF CHANNEL EXIT TO BE WITHIN ENTRANCE PORTAL
WIDTH OF ENTRANCE PORTAL,
30 ft
RUNWAY ℄
QUALITY MARKS
APPROACH CHANNELS
1
4
8
31 ft
CHANNEL AXIS
8
ACTUAL GROUND TRACK
4
1
3000 ft

Fig.10 Principle of assessment of approach ground-track quality (example: ground-track mark 6)

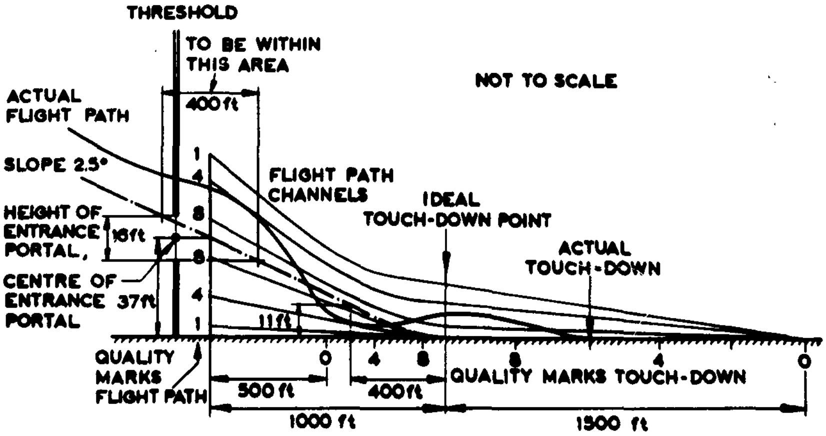

THRESHOLD
TO BE WITHIN THIS AREA
400 ft
NOT TO SCALE
ACTUAL FLIGHT PATH
SLOPE 2.5°
1
4
8
8
4
1
FLIGHT PATH CHANNELS
IDEAL TOUCH-DOWN POINT
HEIGHT OF ENTRANCE PORTAL,
16 ft
ACTUAL TOUCH-DOWN
CENTRE OF ENTRANCE PORTAL
37 ft
11 ft
QUALITY MARKS FLIGHT PATH
0
4
8
8
4
0
QUALITY MARKS TOUCH-DOWN
500 ft
400 ft
1000 ft
1500 ft

Fig. 11 Principle of assessment of quality of landing flight-path and touch-down (example: flight-path mark 4, touch-down mark 6)

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T. van Oosterom
1963
18 pp., incl. 2 refs., 11 figs.

Describes a flight operational method for evaluating the effectiveness of visual approach and landing aids. The method is based on a quantitative appraisal of the guidance obtained from a given configuration of lights and tests are performed on a statistical basis.

This Report was presented at the Aircraft Take-Off and Landing Specialists' Meeting, sponsored by the AGARD Flight Mechanics Panel, held in Paris, 15-18 January 1963.

629.139.15

3g3b2

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